Balancing the (carbon) budget: Using linear inverse models to estimate carbon flows and mass-balance 13C:15N labelling experiments in low oxygen sediments.

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Balancing the (Carbon) Budget: Using linear inverse models to estimate carbon flows and mass-balance ^{13}C:^{15}N labelling experiments in low oxygen sediments.

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Introduction

Approximately 6 % of the continental margin sea floor experiences persistent dysoxia within oxygen minimum zones (OMZs) (Helly & Levin, 2004). OMZs are predicted to grow as a consequence of climate change, with implications for marine biogeochemical cycles (Stramma et al., 2008). The Arabian Sea OMZ impinges upon the Indian continental margin at bathyal depths (150 – 1500 m) generating a depth-dependent oxygen gradient.

In 2008 a multi-national expedition led by Prof Hiroshi Kitazato (JAMSTEC, Japan) investigated the effects of oxygen availability, sediment geochemistry and community structure upon carbon & nitrogen cycling pathways at the Indian margin OMZ. *In situ* ^{13}C-tracer experiments were conducted to quantify OM processing by sediment bacteria and fauna (Witte et al., 2011; Hunter et al., 2012 a; b). However, no empirical data on ^{13}C fluxes from the sediment were available. We closed the carbon budget for each ^{13}C-tracer experiment using linear inverse modelling (LIM) to reconstruct sediment carbon fluxes.

Experimental Design & Model Formulation

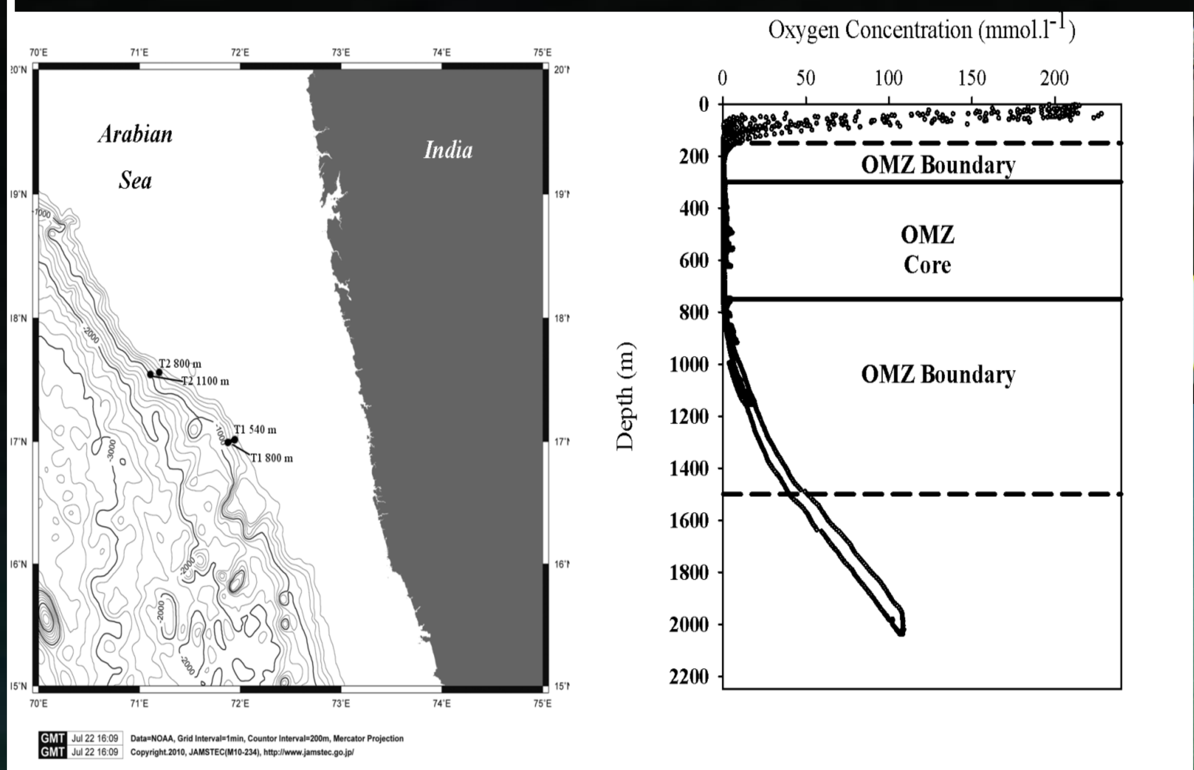


Fig 1. Bathymetric Map of the Indian Continental margin with experimental stations marked (left) & corresponding O_2 profiles (right).

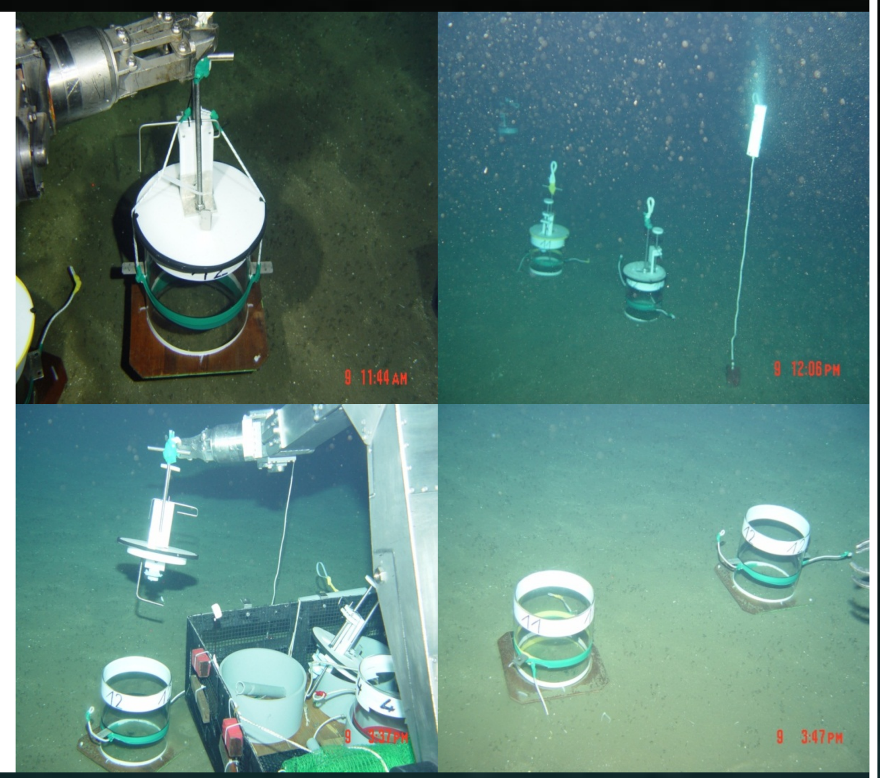


Fig 2. Deployment of semi-enclosed mesocosms at the Indian margin seafloor.

Experimental Design & Data Acquisition

Semi-enclosed mesocosms deployed fixed doses of ^{13}C-labelled diatoms (*Thallassiosira weissflogii)* at the seafloor across the Indian margin OMZ (540 – 1100 m, Figs 1, 2).

The ^{13}C label was traced into sediment OM, bacteria, foraminifera and metazoan fauna (A. Enge & P. Heinz, *unpub. data*; Hunter et al., 2012a; b; Witte et al., 2011).

Linear Inverse Models

Food web models were constructed following Van Oevelen et al. (2010).
Food web components and flow linkages were fixed *a priori*.
Flow magnitudes were constrained using data from the mesocosm experiments.
Final model solutions were obtained by Bayesian sampling for best fit from 25,000 iterations of each model.

Linear Inverse Modelling Solutions

T1 540 m T1 800 m T2 800 m T2 1100 m

< 1.5 mmol C m-2 d-1

< 0.15 mmol C m-2 d-1

Taxa

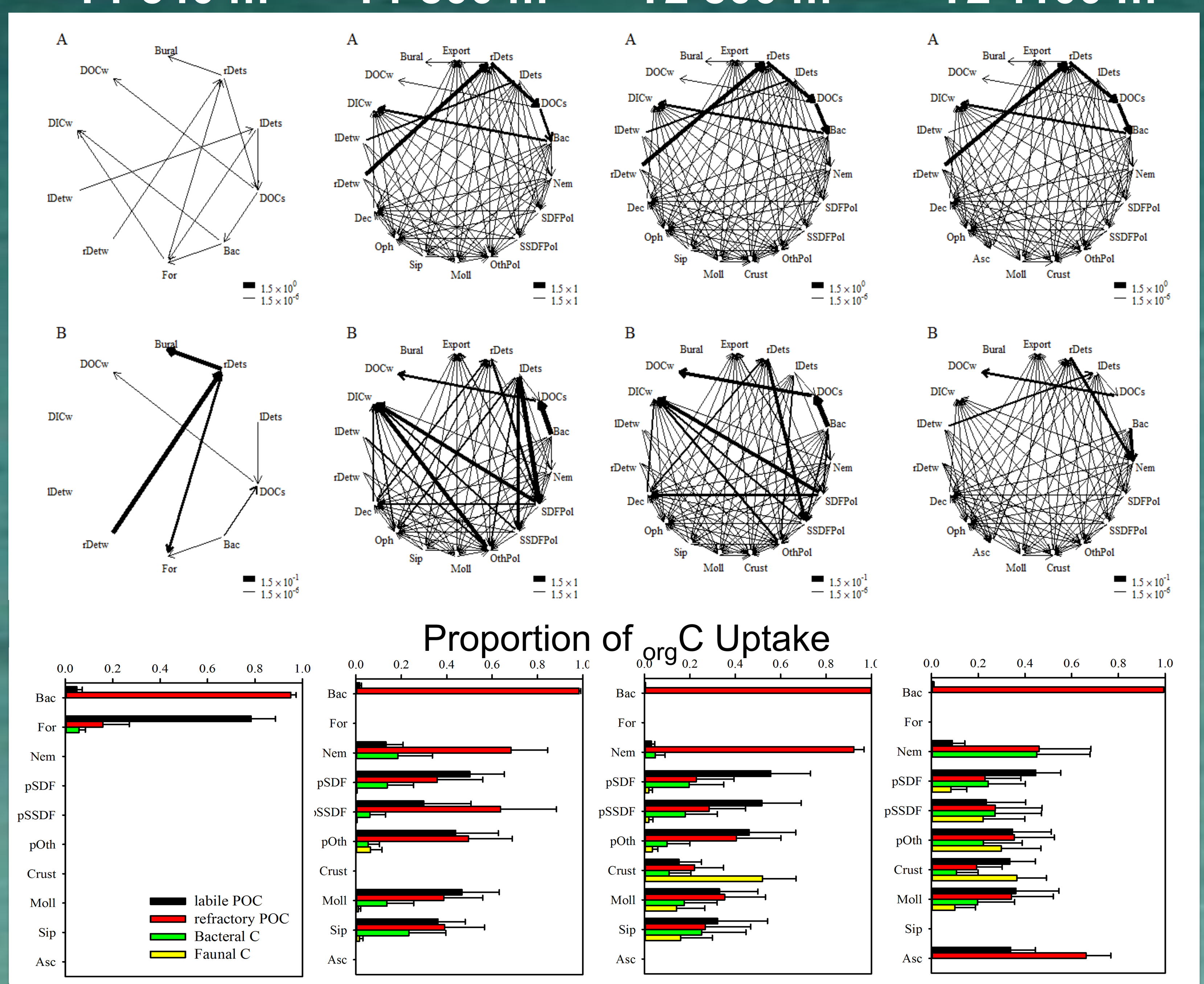
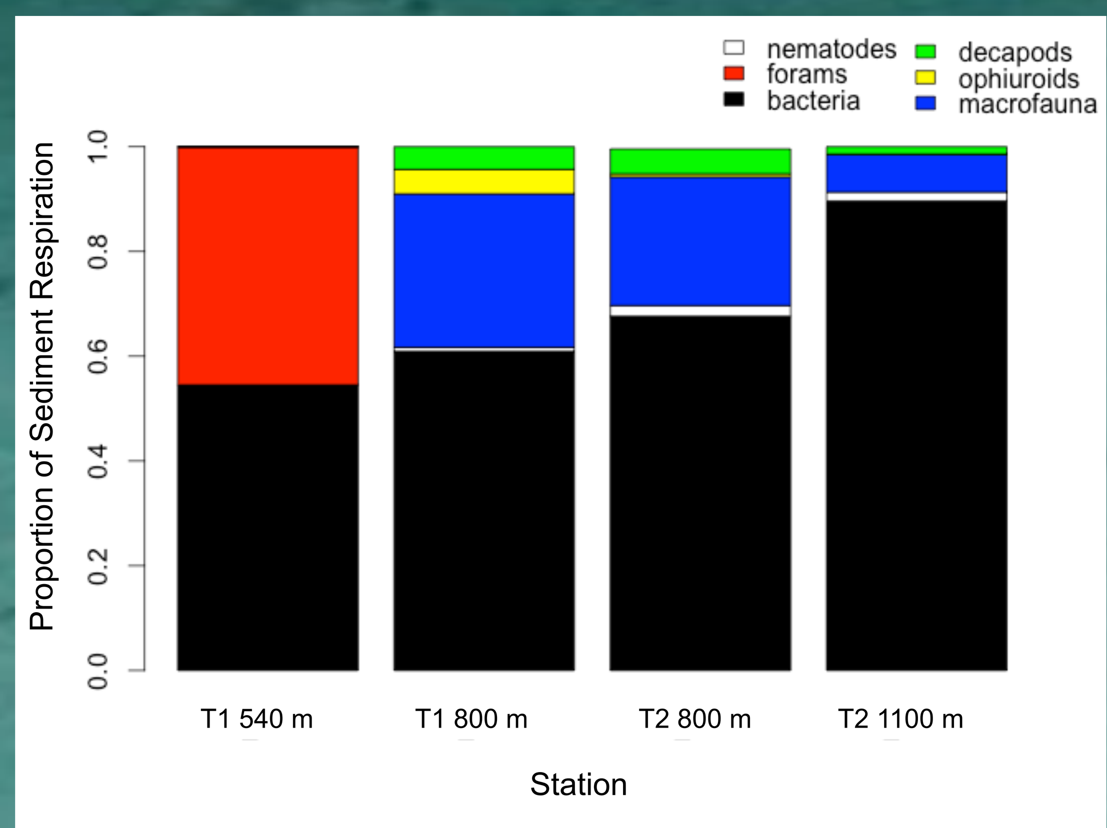


Fig 3. LIM solutions for carbon flows across the Indian margin OMZ. Barcharts reveal contributions of detrital, bacterial and faunal OM sources to organismal carbon budgets.

Abbreviations: lDet, labile detrius; rDet, refractory detritus; Bac, Bacteria; Nem, Nematodes, SDFPol / pSDF Surface Deposit Feeding polychaetes, SSDFPol / pSSDF, subsurface deposit feeding polychaetes; Othpol / pOth, other polychaetes Crust, macrofaunal crustacea; Moll, molluscs; Sip, sipunculans; Asc, ascidians; Oph, megafaunal ophiuroids; Dec, megafaunal decapods



	T1 540 m	T1 800 m	T2 800 m	T2 1100 m
Sed. Respiration (μmol C. m^{-2}. d^{-1})	358.40	1089.00	1088.00	923.30
Standard Deviation	3.63	4.55	7.73	20.69

Fig 4. Sediment community respiration and the relative contributions of bacteria and major faunal groups estimated from LIM solutions.

Summary

1. Food-web model complexity increases concomitantly with oxygen availability.
2. Across the Indian margin OMZ labile phytodetritus was primarily processed by foraminifera and metazoan macrofauna.
3. LIM estimates community respiration to be greatest at the 800 m stations, driven by higher metazoan faunal contributions.
4. Bacterial contributions to sediment respiration increased concomitantly with the depth-dependent oxygen gradient.
5. At present, foraminiferal data are only available for station T1 540 m. Foraminifera must be integrated into all models to accurately reconstruct sediment carbon fluxes.

Acknowledgements

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